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Stubble-Mulch Farming on Wheatlands of the Southern High Plains[1]

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PROBLEMS INVOLVED IN STUBBLE-MULCH FARMING IN THE SOUTHERN HIGH PLAINS

CLIMATIC HAZARDS

A major problem confronting the farmer in the southern High Plains is the difficulty of utilizing the erratic and variable rainfall for crop production. Precipitation occurs chiefly during the late spring and early summer months and is derived from humid maritime air

[1] This circular supplements and enlarges upon Texas Agricultural Experiment Station Bulletin No. 711, "Stubble-Mulch Management for Water Conservation and Erosion Control on Hardlands of the Southern Great Plains" by C. J. Whitfield, C. E. Van Doren, and Wendell C. Johnson. Its purpose is to meet a widespread demand for information concerning stubble-mulch farming on the part of farmers of the southern High Plains, an area comprising eastern New Mexico, southeastern Colorado, southwestern Kansas, and the Panhandles of Oklahoma and Texas.

[2] The studies on which this circular is based were made at the Amarillo Conservation Experiment Station and are cooperative between the Soil Conservation Service, Research, and the Texas Agricultural Experiment Station.

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originating over the Gulf of Mexico. The moist air normally moves northward from the Gulf with a clockwise curvature to the eastward. Skirting the east side of the Texas Panhandle, it releases its moisture over the more humid areas to the east. On occasions, however, the approach of a transient storm from the west diverts the flow to the westward.

When this occurs the moist air arrives in the Texas Panhandle in a highly unstable state, due partly to its original coolness and high humidity, partly to the intensifying effect of being lifted over rising terrain with increasing distance from the Gulf. The resulting rains occur usually in the form of torrential showers, frequently accompanied by hail and occasionally by tornadoes. As a result of the great difference in moisture content of air masses over the southern High Plains and the irregularity of their occurrence, rainfall in the area is extremely variable. During the 8 years that stubble-mulch studies have been carried on at Amarillo, the smallest amount of precipitation per crop year, 13.5 inches, occurred in the 1945-46 crop season and the largest amount, 27 inches, in the 1948-49 season. Annual precipitation at Amarillo for 58 years of record has ranged from 11 to 40 inches.

Soil Conditions

Because the summer precipitation is rather scanty and often torrential, it is imperative that the soil be managed so as to allow it to absorb and retain as much moisture as possible. This is not easily accomplished, since the hard-land soils of the southern High Plains tend to run together, swell greatly when wetted, and are deficient in noncapillary pore space. In late summer, for example, the surface soil of Pullman clay loam, the dominant soil type, nearly always has a volume weight of 1.4 or greater.

Under such conditions, stubble mulching comes into its own (fig. 1). The surface residues break up the water films that greatly restrict infiltration. In addition, the mulch intercepts the raindrops and minimizes the disintegrating effect of their impact on the soil granules.

The soil is pulverized less by subtillage than by the scraping action of the disks of the one-way plow. The decay of plant residues and the formation of decomposition products that stabilize the soil aggregates takes place mainly at the surface, where it is most needed. Since only one-fifth of the annual precipitation in an average year becomes soil moisture under the conditions prevailing in this area, promoting the elimination or reduction of runoff is of utmost importance. There is no single practice that will achieve this objective, although leaving crop residues in the form of a stubble mulch is one of the most effective practices for increasing the permeability of the surface soil. To secure the greatest possible retardation of runoff, stubble-mulch tillage should be supported by other practices such as contour farming and terracing.

Wind movement is heaviest during the winter and early spring months, the period during which the soil is most subject to erosion by wind. March, the month of greatest wind movement, has 43 percent more wind on an average than does August, the month of least wind.

FIGURE 1.—*A*, Straw residue from 36-bushel-per-acre wheat crop after initial subtillage operation; *B*, subtilled continuous-wheat plot after second cultivation with 30-inch sweeps.

The absence of growing vegetation and the rather "fluffy" or incoherent nature of the soil in the early part of the year tend to increase the hazard of blowing. The value of a surface mulch in reducing wind velocities near the surface of the ground and combating wind erosion has long been recognized. Stubble mulching also reduces evaporation.

A surface mulch helps to prevent excessive crusting of a heavy soil. At times a heavy rain may occur before the recently planted wheat has emerged. A hard crust which the wheat seedlings have difficulty in penetrating then forms. Stubble mulch tends to soften this crust and makes it easier for the seedlings to emerge. Much difficulty from crusting occurs when the wheat is "dusted in" or planted in dry soil and must await a rain to germinate. Use of a furrow-type drill will eliminate much of the difficulty by placing the seeds nearer to moisture. This practice results in more reliable germination. A furrow-type drill also operates better in heavy residues than does a disk-type drill.

Insects and Winter Annuals

The criticism is sometimes heard that a surface mulch of plant residues will harbor insects and increase insect damage to the crop. No unusual difficulty with insects due to subtillage has been experienced at the Amarillo station.

Another criticism sometimes directed at subtillage is that its use tends to encourage and increase the growth of winter annuals such as goat grass and little barley. These weeds, which germinate at about the same time as drilled wheat, tend to escape destruction in preplanting cultivations. Unusual difficulty with winter annuals on subtilled land has not been experienced at the Amarillo station. It is questionable whether any method of tillage will entirely eliminate them where wheat is raised on the same land year after year. Where they are a problem it is advisable to raise wheat on a fallow system. This permits cultivation during the spring and summer in alternate years until the infestation of winter annuals is brought under control.

THE AMARILLO STATION STUBBLE-MULCH PROJECT

Lay-out of Plots

In 1941 a series of ⅓-acre plots was established for the purpose of comparing subtillage and tillage by conventional methods in the production of winter wheat. On plots of continuous wheat, subtillage was compared with tillage by the moldboard and one-way plows. On plots of wheat on fallow, subtillage was compared with tillage by the one-way plow. The subtillage tool used at first was the Noble cultivator, a machine developed by a wheat farmer in Alberta, Canada. This was later supplemented by a subtillage machine designed and built at the Amarillo station.

Supplementary Studies

At the close of the 1949 harvest a total of 8 years of grain-yield data from the continuous-wheat plots and 7 years' data from the wheat-on-

fallow plots had been accumulated. In addition, in most years straw yields were determined. Studies of soil moisture and soluble nitrogen were made from time to time, and beginning with the 1948–49 season a running account was kept of the levels of soil nitrate-nitrogen and moisture to a depth of 4 feet on the stubble-mulch plots, with determinations made about five times annually. This provided information vital to an understanding of the effect of the stubble mulch on the crop and soil.

In 1949, chemical analyses of the forage and grain furnished data on the effect of stubble mulching on the nitrogen content of the crop.

A comprehensive study of the effect of land use on organic matter, structure, and the level of soluble phosphorus of the soil was begun and partially completed in 1949. This work will yield additional information concerning the effect of stubble mulching.

Development of Subtillage Machine

Soon after the beginning of the stubble-mulch project it became apparent that subtillage was not being done effectively by any of the tools available at that time. The development of a suitable subsurface tool was vital to the success of the studies at the station and a virtual necessity if subtillage was to be accepted by the farmers on a widespread scale in regular farming operations. In 1945, Amarillo station workers, after extensive study of the problems connected with stubble-mulch farming, developed a machine which has been used successfully since that time.

RESULTS

Yields

Except for 2 of the 8 years of record, 1942 and 1949, subtilled continuous wheat outyielded wheat grown on plots cultivated with the one-way and moldboard plows (table 1). In the case of wheat on fallow, the yield of subtilled wheat equalled the yield on one-wayed land in one of the 7 years of record, and outyielded wheat on one-wayed land in the other 6 years. When subtillage was delayed until the first cultivation on April 1, subtilled wheat outyielded one-wayed wheat each year.

The beneficial effect of subtillage on yield noted here is quite different from the results obtained in more humid parts of the country, where subtillage under certain conditions tends to lower yields unless supplementary fertilizer is used. The experimental data show that farmers in the southern High Plains do not need to make a sacrifice in crop yield in order to practice stubble-mulch farming as a soil conservation measure.

TABLE 1.—*Grain yields of continuous wheat and wheat on fallow obtained on differently tilled plots, 1942–49*

Tillage practice	Yield per acre								
	1942	1943	1944	1945	1946	1947	1948	1949	Average 1942–49 [1]
Continuous Wheat									
	Bu.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
Moldboard	20. 3	4. 2	19. 7	4. 4	1. 8	31. 8	5. 6	23. 2	13. 9
One-way	20. 1	6. 0	24. 5	6. 3	2. 6	28. 4	4. 6	21. 5	14. 2
Subtillage	19. 0	7. 1	26. 4	6. 9	6. 0	34. 3	6. 2	19. 4	15. 7
Wheat on Fallow									
One-way	------	11. 9	28. 4	16. 7	8. 5	33. 1	13. 9	36. 0	21. 2
Subtillage	------	14. 6	28. 4	20. 4	13. 9	36. 8	15. 7	38. 4	24. 0
Delayed subtillage [2]	------	12. 9	30. 3	23. 3	15. 4	36. 2	15. 6	36. 1	24. 3

[1] Averages for wheat on fallow are for 1943–49.
[2] Subtillage in which the first operation is delayed until approximately Apr. 1.

It will be noted that the average yield of two crops of continuous wheat is greater than that of one crop of wheat on fallow. This means that over a period of years a farmer would normally produce less wheat on a given tract by using a fallow system than by growing a crop on the land year after year. The difference amounts to between 3 and 4 bushels per acre per year. The reduction in yield under the fallow system is largely offset by the smaller expense of production due to the elimination of one year's harvesting and seeding operations.

In unusually dry years, the yield of wheat on fallow makes an especially favorable showing in comparison with continuous wheat. In 1945, 1946, and 1948, for example, the yield of wheat on fallow was at least double that of continuous wheat. It is likely that a farmer could raise wheat on fallow during periods of subnormal precipitation without any loss of income. This would be especially true if delayed fallow were practiced, which would eliminate the expense of two or three tillage operations per crop without decreasing yields. During drought years, raising wheat on fallow may be the only means of producing enough residues to protect the soil.

Reasons for Increased Yields With Stubble Mulch

Most of the cultivated land in the southern High Plains was broken out of grass in comparatively recent times, during or subsequent to

World War I. Although each wheat crop harvested removes nutrients from the soil, it is generally agreed that moisture rather than fertility is the limiting factor in crop production in this area.

Rainfall in the southern High Plains averages only 15 to 25 inches per year. Not only is much of the rainfall lost by runoff but the efficiency of the rather meager precipitation is lowered by the high wind movement, low relative humidity, and the fact that 10 of the 19 inches of average precipitation (at the Amarillo station), or 53 percent, occurs during the warm season from May through August. These conditions account for the previously mentioned fact that only 20 percent of the annual precipitation becomes soil moisture. At the close of the 1948–49 fallow season on July 7, 1949, for example, only 5 of the 27 inches of precipitation, or 18.5 percent, could be accounted for as available soil moisture in the upper 4 feet of soil.

Soil-moisture data for past years show that soil moisture is not consistently higher under subtilled continuous wheat than under one-wayed wheat. Generally, however, subtilled land accumulates more moisture during a year of fallow than does one-wayed land. It is apparent that the increased yields with stubble mulch cannot be attributed entirely to improved moisture relationships.

Calculation of the ratio of weight of straw to weight of grain for the wheat crop shows that a lower straw-grain ratio is consistently obtained with subtilled wheat than with one-wayed wheat. This is true both for continuous wheat and for wheat on fallow. Lower ratios, or more grain per given weight of straw, usually occur in wet years than in dry years. Ratios are also generally lower for wheat on fallow as compared to continuous wheat (table 2).

TABLE 2.—*Ratio of weight of straw to weight of grain in wheat crop, and precipitation in corresponding crop year or 2-year crop period*

STRAW-GRAIN RATIO, CONTINUOUS WHEAT

Tillage practice	1943	1944	1945	1946	1947	1948 [1]	1949	Average 1943–49
Moldboard	5. 26	2. 98	2. 74	7. 64	2. 02	-----	2. 86	[2] 3. 92
One-way	4. 03	1. 84	1. 59	4. 49	2. 15	----	2. 94	[2] 2. 84
Subtillage	3. 55	1. 32	1. 06	2. 89	1. 73	-----	2. 78	[2] 2. 22
Precipitation per crop year inches	17. 3	21. 2	15. 7	13. 5	20. 8	-----	27. 0	-------

STRAW-GRAIN RATIO, WHEAT ON FALLOW

Tillage practice	1943	1944	1945	1946	1947	1948 [1]	1949	Average 1943–49
One-way	3. 18	1. 84	0. 92	2. 89	-----	-----	2. 76	[3] 2. 32
Subtillage	2. 81	1. 85	. 84	2. 01	-----	-----	2. 76	[3] 2. 05
Precipitation per 2-year crop period inches	43. 8	38. 5	36. 9	29. 2	34. 3	-----	40. 7	-------

[1] No record for 1948.
[2] 1948 not included.
[3] Averages for wheat on fallow are for the 5 years shown.

The low straw-grain ratios under stubble mulch may be due to a lower level of available nitrogen in the soil or to a higher level of available phosphorus. A high level of available nitrogen is recognized as causing a rank growth and a high straw-grain ratio. The amount of soluble phosphorus, another soil fertility factor, may be responsible since phosphorus has an effect opposite to that of nitrogen and may counteract the effect of excessive nitrogen.

The spring of 1949 was characterized by an abundance of rainfall. Nine inches, or about half of the mean annual precipitation, was received during the 2 months of April and May, and over a third of the mean annual amount fell during the month of May alone. As a consequence of the heavy spring precipitation, heavy demands on soil fertility were made by the crop and marked nitrogen deficiency symptoms developed. The chlorotic appearance and reduced growth of wheat on the subtilled continuous-wheat plots were very conspicuous but there was little difference in appearance of the wheat-on-fallow plots attributable to the method of cultivation which had been used. Marked differences in the protein content of wheat forage samples taken on April 25 were revealed by chemical analysis (table 3).

TABLE 3.—*Dry weight, nitrogen, and protein content of wheat forage grown on differently tilled plots, Apr. 25, 1949*

Tillage practice	Dry weight per acre	Protein content (N×6.25)	Nitrogen per acre
CONTINUOUS WHEAT			
	Pounds	*Percent*	*Pounds*
One-way	1, 217	15. 8	31
Moldboard	1, 674	15. 4	41
Subtillage	1, 070	12. 9	22
WHEAT ON FALLOW			
One-way	2, 744	16. 5	73
Subtilled	3, 222	13. 4	69
Delayed subtilled	3, 528	12. 7	72

There was nearly twice as much nitrogen per acre in the forage from the moldboard-plow plots in continuous wheat as in the forage from the subtilled plots. This indicates that marked differences in nitrification rate resulted from varying the type of tillage.

Since as much as three-fourths of the nitrogen contained in the forage of the wheat plant is later translocated to the head as the grain matures, it is not surprising that the difference in the amount of nitrogen in the forage in late April should later show up as a difference in the protein content of the mature grain (table 4).

Table 4.—*Protein content, yield, and pounds of nitrogen per acre in wheat grain from differently tilled plots, 1949*

Continuous Wheat

Tillage practice	Protein (N×5.7)	Yield per acre	Nitrogen per acre
	Percent	*Bushels*	*Pounds*
One-way	12. 81	21. 5	29. 0
Moldboard	12. 92	23. 2	31. 5
Subtillage	12. 22	19. 4	24. 9
Wheat on Fallow			
One-way	14. 05	36. 0	53. 2
Subtillage	13. 26	38. 4	53. 6
Delayed subtillage	12. 41	36. 1	47. 1

Protein content of the grain ranged from 12.22 percent for continuous subtilled wheat to 14.05 percent for one-wayed wheat on fallow. A protein content of 12 percent is adequate for milling purposes. Any excess could be considered a luxury consumption of nitrogen by the crop and a higher protein content than is needed to meet market requirements.

The low nitrogen content of wheat forage and grain on the subtilled plots (table 5) reflected the low available soil-nitrogen content of these plots throughout the season.

The data in this table show that on October 10 the subtilled continuous-wheat plots contained only one-half as much available moisture as the one-wayed plots. They also apparently contained less available nitrogen. The October nitrogen data, however, do not give a complete picture. By the last half of March, the subtilled plots had absorbed sufficient moisture to reverse this relationship and contained 3.9 inches of available water, compared with 2 inches on the one-wayed plots. This moisture advantage was still apparent in the subtilled plots at the July sampling date following harvest, when 1.3 inches more available water was present in the subtilled plots than in the one-wayed. This inch of stored moisture is equivalent to 6 inches of rainfall, or about one-third of the annual precipitation.

The relatively large amount of soil moisture in the subtilled land was associated with a smaller amount of soluble nitrogen, the subtilled plots averaging 54 and 51 pounds of NO_3-N at the late March and late May sampling times, respectively, compared with 88 and 76 pounds for the one-wayed plots on the corresponding dates. From late May until harvest, the supply of soluble nitrogen in the one-wayed plots decreased by 26 pounds per acre. This is a sizable amount of nitrogen to be absorbed by the crop during that period. This amount plus the 31 pounds present in the crop on April 25 totals 57 pounds which exceeds the total amount of nitrogen estimated to be in the crop at harvest time. (At harvest time, 29 pounds were known to

be in the grain and 18 pounds were estimated to be in the straw, a total of 47 pounds of nitrogen in straw and grain based on the assumption of a straw-grain ratio of 2.9, a yield of 21 bushels per acre, and a nitrogen content in the straw of ½ of 1 percent).

TABLE 5.—*Nitrate-nitrogen and available moisture in upper 4 feet of soil on differently tilled plots, 1948–49 season*

Tillage method	Sampling dates[1]							
	Oct. 10		Mar. 18, 31		May 20, June 1		July 7, 8	
	NO_3–N[2] per acre	Water	NO_3–N per acre	Water	NO_3–N per acre	Water	NO_3–N per acre	Water
	Pounds	*Inches*	*Pounds*	*Inches*	*Pounds*	*Inches*	*Pounds*	*Inches*
CONTINUOUS WHEAT								
One-way	31	1.4	88	2.0	76	2.8	50	0.4
Moldboard		1.2	81	2.5	75	2.2	56	.6
Subtillage	12	.7	54	3.9	51	4.3	45	1.7
WHEAT ON FALLOW								
One-way	44	2.5	135	2.5	81	1.8	62	0.4
Subtillage	53	5.7	93	3.7	32	1.5	42	.6
Delayed subtillage			65	4.5	34	2.8	37	1.1
FALLOW								
One-way	36	1.8	222	3.4	217	5.2	226	4.8
Subtillage	18	1.0	145	4.9	157	5.8	111	5.8
Delayed subtillage			152	4.9	136	5.6	139	5.3

[1] Where 2 dates are given, data are mean for 2 replications, 1 replication having been sampled on each date.
[2] Nitrogen data for Oct. 10 are for top 6 inches of soil only.

Evidently, either leaching losses occurred or the decay of dying root material had progressed to the point that on July 7 considerable soluble nitrogen had been tied up in microbial cell material. It is interesting to note that although there was at least 45 pounds per acre of available nitrogen in the soil of the subtilled continuous wheat plots, the plants on these plots showed marked visible nitrogen-deficiency symptoms. The wheat on subtilled fallow, on the other hand, showed no visible nitrogen deficiency symptoms even though the soluble-nitrogen supply at times was less than 35 pounds per acre. The difference in behavior was apparently due to the development of a more elaborate root system on the fallow plots which enabled the

plants to deplete soil nitrates to a lower concentration. The development of the roots on the continuous-wheat plots may have been inhibited by shallow penetration of moisture in the fall.

The most striking feature of the data from the wheat-on-fallow plots is the larger amount of soluble nitrogen in the one-wayed plots compared with the subtilled plots. Also, the moisture supply generally held up better under subtillage. There was little difference in yield attributable to the mode of tillage, but a considerable difference was noted in the protein content of the grain (table 4). In this instance, as before, the practice of subtillage caused lower protein contents.

The available nitrogen in the soil of the plots in fallow either showed no important increases or showed decreases between the late March and the early July sampling dates. One explanation of this is that nitrates were being removed by leaching by the heavy spring rains as fast as they were formed. The large amount of soluble nitrogen in the soil in July (111 to 226 pounds) is much more than would be needed for an average 30-bushel wheat crop, which contains only about 60 pounds per acre of nitrogen in grain and straw. The practice of fallowing would appear to be wasteful of nitrogen in a wet year, and leaching of nitrogen may be a factor in the greater difficulty experienced in maintaining organic matter in the soil under a fallow system of farming. The amount of soil organic matter is a function of the total nitrogen content of the soil.

Soil Organic Matter

Soil organic matter, consisting of the decayed residues of plants, makes up about 2 percent by weight of the average cultivated hardland topsoil in the southern High Plains. Although present in relatively small amounts, organic matter or humus plays a disproportionately great part in determining the soil's productivity. Besides imparting good tilth and desirable water-holding properties to the soil, it serves as a storehouse of nutrients for the growth of both plants and microorganisms. Evaluation of any cropping or tillage system would not be complete without examining the effect of the cropping or tillage system on soil organic matter.

Composite samples, taken from the top 6 inches of soil at the time the stubble-mulch plots were established in 1941 and analyzed for organic-matter content by a wet combustion method, contained an average of 2.44 percent organic matter. The organic-matter content for the 0- to 3-inch and 3- to 6-inch depths of soil in 1949 provided information concerning the present status of the plots (table 6). As a matter of interest, the organic-matter content of a virgin buffalo grass-blue grama pasture is also given. Loss of organic matter from the top 6 inches of soil since 1941 occurred on all of the plots and averaged 13 percent of the 1941 total for the continuous-wheat plots and 18 percent for the wheat-on-fallow plots. The subtilled fallow plots and continuous-wheat plots showed a greater conservation of soil organic matter than did the corresponding one-wayed plots. Raising continuous wheat is more conservative of organic matter than raising wheat on fallow.

TABLE 6.—*Organic-matter content of differently tilled plots, 1949*

Tillage practice	Depth below surface		
	0 to 3 inches	3 to 6 inches	Average, top 6 inches
CONTINUOUS WHEAT			
	Percent	*Percent*	*Percent*
One-way	2. 11	2. 10	2. 10
Subtillage	2. 20	2. 09	2. 14
Moldboard	2. 03	2. 08	2. 06
WHEAT ON FALLOW			
One-way	1. 96	1. 88	1. 92
Subtilled	2. 07	1. 99	2. 03
VIRGIN PRAIRIE			
Untilled	3. 01	2. 27	2. 64

SOLUBLE PHOSPHORUS

Soluble-phosphorus determinations of the top 3 inches of soil of the differently tilled plots furnished a clue to the possibility of the phosphorus status of the soil having been altered by the method of cultivation. The soluble-phosphorus content of the subtilled fallow plots and continuous-wheat plots both averaged 6.1 parts of phosphorus per million parts of soil. The one-wayed plots averaged 6.2 and 5.6 parts per million for the continuous-wheat and wheat-on-fallow plots, respectively. The moldboard-plow continuous-wheat plots showed 5 parts per million of soluble phosphorus. With the method of analysis used, soils having less than 10 parts per million of soluble phosphorus are rated as being low in that nutrient. It does not appear likely that noteworthy differences in the amount of soluble phosphorus are caused by the tillage method used.

SOIL STRUCTURE

As an approach to the study of the effect of different cultural practices on soil structure, some 400 volume-weight determinations were made on samples of fine-textured silty clay loam soil taken at the Amarillo station. Some of these determinations were made on one replication of the stubble-mulch plots (table 7). The unusually high volume weights of these soils are evidence of a small amount of pore space and partly explain the difficulty experienced by irrigation farmers in getting the Pullman soils to take water. The soils on the one-wayed and subtilled continuous-wheat land had about the same volume weights for corresponding depths and were less dense than the virgin prairie soil and the soil under moldboard continuous wheat.

The prairie soil and the soil under moldboard continuous wheat were similar in volume weight. There is no evidence that subtillage resulted in the formation of a plowsole. Although the greatest density of the soil profile was in the 9- to 12-inch layer, this condition also prevailed on land that had never been cultivated. Volume weights of the 1- to 5-foot interval of the Pullman soils are rather uniform, being about 1.70. The low volume weight in land broken out of grass appears to be due mainly to changes brought about by the decay of fibrous roots rather than to any change taking place while the grass is growing. The top inch of grass-covered soil, where a thin mulch of loose soil granules frequently forms under a thin surface crust, may be an exception.

Table 7.—*Volume weight of soil under different tillage practices, August 1949*

Tillage practice	Depth below surface			
	0 to 3 inches	3 to 6 inches	6 to 9 inches	9 to 12 inches
Continuous Wheat				
One-way	1. 36	1. 41	1. 63	1. 76
Subtillage	1. 38	1. 43	1. 66	1. 76
Moldboard	1. 41	1. 52	1. 73	1. 78
Wheat on Fallow				
Subtillage	1. 42	1. 56	1. 74	1. 83
One-way	1. 37	1. 50	1. 71	1. 81
Virgin Prairie				
Untilled	1. 40	1. 51	1. 74	1. 80

Development and Use of Subtillage Machine

At the start of the stubble-mulch experiments, attempts were made to improvise a subtillage machine by attaching commercially available sweeps to carriers such as listers or tractor-attached tool bars. These efforts were found to be impractical for one or more of the following reasons:

1. The implement was not strong enough to stand the strain of the initial tillage in hard soils.
2. Clogging occurred because the frame was not high enough above the ground or the shanks of the sweeps were too close together.
3. Either the sweep was poorly designed or an adjustment was not provided to permit tilting the sweep at the most efficient angle. This caused the blades to become fouled and resulted in a poor kill of weeds. The draft of the machine was also heavy.

The best angle between the blades of the sweep has proved to be 60°. The sweep should be operated "flat," in a horizontal position. It is also advisable to have a rolling coulter ahead of the sweep.

After an extensive study of the problem, Amarillo station technicians designed and built a subtillage tool which has been operated successfully in hard-land soils through surface residues ranging in amounts up to 6,000 pounds per acre. This machine (fig. 2) consists of five 30-inch Dempster sweeps mounted on a heavily reinforced carrier equipped with power lifts and rolling coulters. The weight of the machine is 2,000 pounds, which is supplemented as needed with as much as 1,000 pounds of added weight. The weight of the machine combined with the proper application of the line of draft through a

Figure 2.—Subtillage machine, developed at the Amarillo station, operating in first cultivation of heavy wheat stubble.

special adjustable hitch makes it possible to plow at controlled depths with the sweeps in a level position, so that a minimum of power is needed.

Farmers using subsurface tillage in hard, dry ground during the first plowing operation generally find that tilting the points of the sweeps downward in an attempt to keep the machine in the ground results in inferior work. The draft is greatly increased, the depth of plowing is not uniform, and the soil becomes ridged. The solution of this difficulty is simply applying more weight to the machine so that the sweeps will run flat with the cutting edges in a horizontal plane.

Commercial implements embodying a number of the features required for successful stubble-mulch farming are now on the market (fig. 3). In choosing a subtillage machine, the farmer should keep

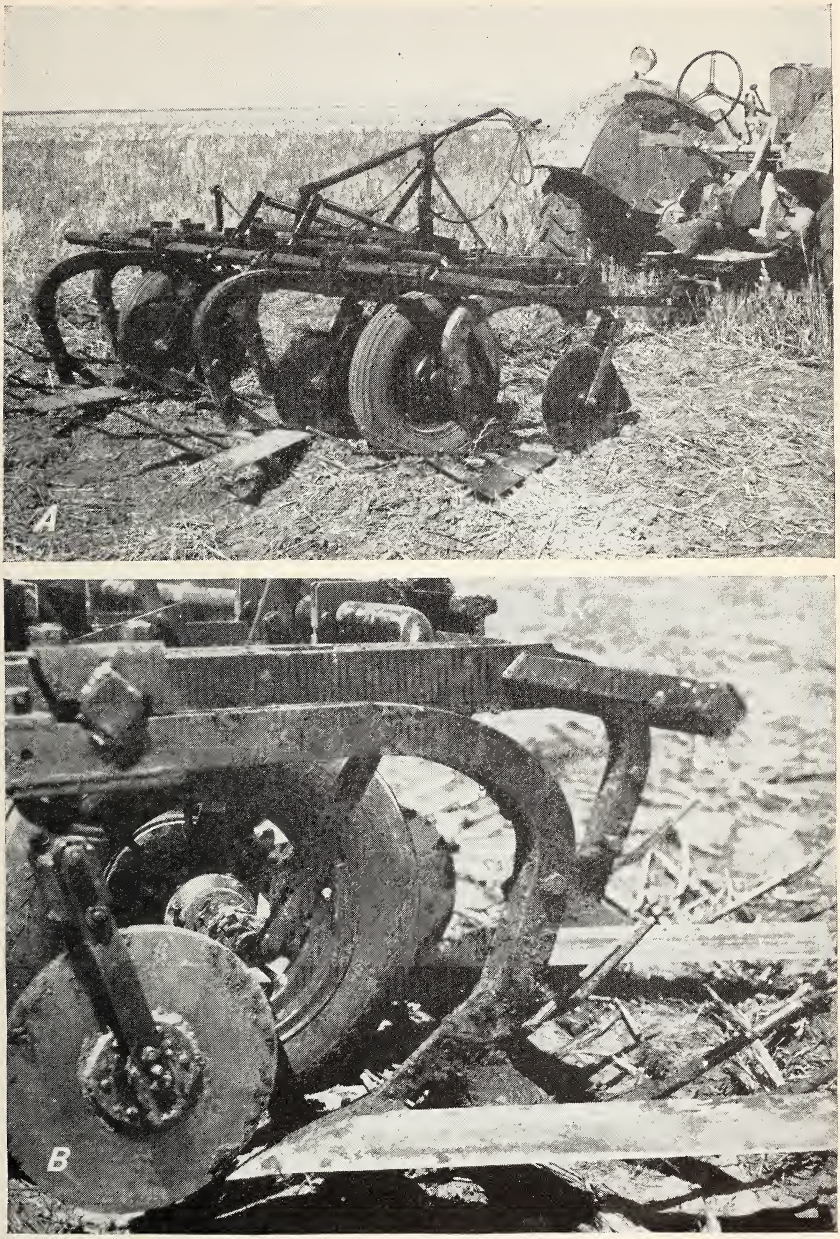

Figure 3.—A commercially manufactured subtillage machine developed by one of the leading implement companies and placed on the market in the fall of 1949. *A*, General view; *B*, near view showing 30-inch sweeps and rolling coulters.

in mind several basic requirements. The machine should: (1) Be capable of operating at controlled and uniform depths; (2) be equipped with rolling coulters to cut residues and weeds ahead of the

sweeps to prevent clogging; (3) have adequate weight and strength for penetration and operation under unfavorable soil conditions; and (4) be able to cultivate the soil with sufficient effectiveness to kill weeds and volunteer crops such as wheat.

IMPORTANT TECHNIQUES IN STUBBLE-MULCH FARMING WITH WINTER WHEAT

Proper Condition of Straw for Tillage

The combine should have an efficient straw spreader to avoid leaving the straw in windrows. This will eliminate a common source of clogging at the outset.

Cultivate at the Proper Time and Depth

Unless delayed fallow is being practiced, the first cultivation is started as soon as possible after harvest before the soil becomes too hard and dry. The first cultivation is made at the greatest depth and each successive cultivation should be shallower to insure a firm seedbed at planting time. If the land is to be fallowed for a year, the first cultivation is made to a depth of from 4 to 5 inches. If continuous wheat is being raised and the land will be reseeded in the fall following harvest, a depth of 3 or 4 inches will be about right. In the first tillage operation the amount of power required to pull a subtillage machine is about the same as that needed to pull a one-way plow operating at the same depth. In later operations the subtillage machine will require a little less power than the one-way. The speed at which the sweep machine is pulled has little effect on the quality of the work. In this respect it differs from the one-way, which covers less residue at low speeds and "throws" soil at high speeds.

In most years, three cultivations in the fall will adequately place the land in a satisfactory condition for seeding. If the land is to be fallowed the next season, four additional cultivations will be necessary during the following spring and summer. The number of cultivations will be the same as would be needed with a one-way plow except in occasional years when heavy rains, occurring soon after the field is undercut, enable the weeds to reset themselves. At such times an extra cultivation with the sweep machine will be required. In judging whether this extra cultivation is advisable, consideration should be given to the kinds of weeds and their growth habits. Taprooted plants, for example, after having been undercut and then revived by the rain, often are able to draw moisture from only the upper few inches of soil. This use of soil moisture may not be serious, as the moisture would later be lost by evaporation regardless of the weeds. Pigweeds have a very low moisture requirement and remain alive with only a single branch root in loose, moist soil.

Drill the Crop Properly

Drilling wheat on land prepared with the subsurface tillage machine when exceptionally heavy crop residues remain on the surface requires the use of a shovel-type drill (fig. 4). The drill rows should

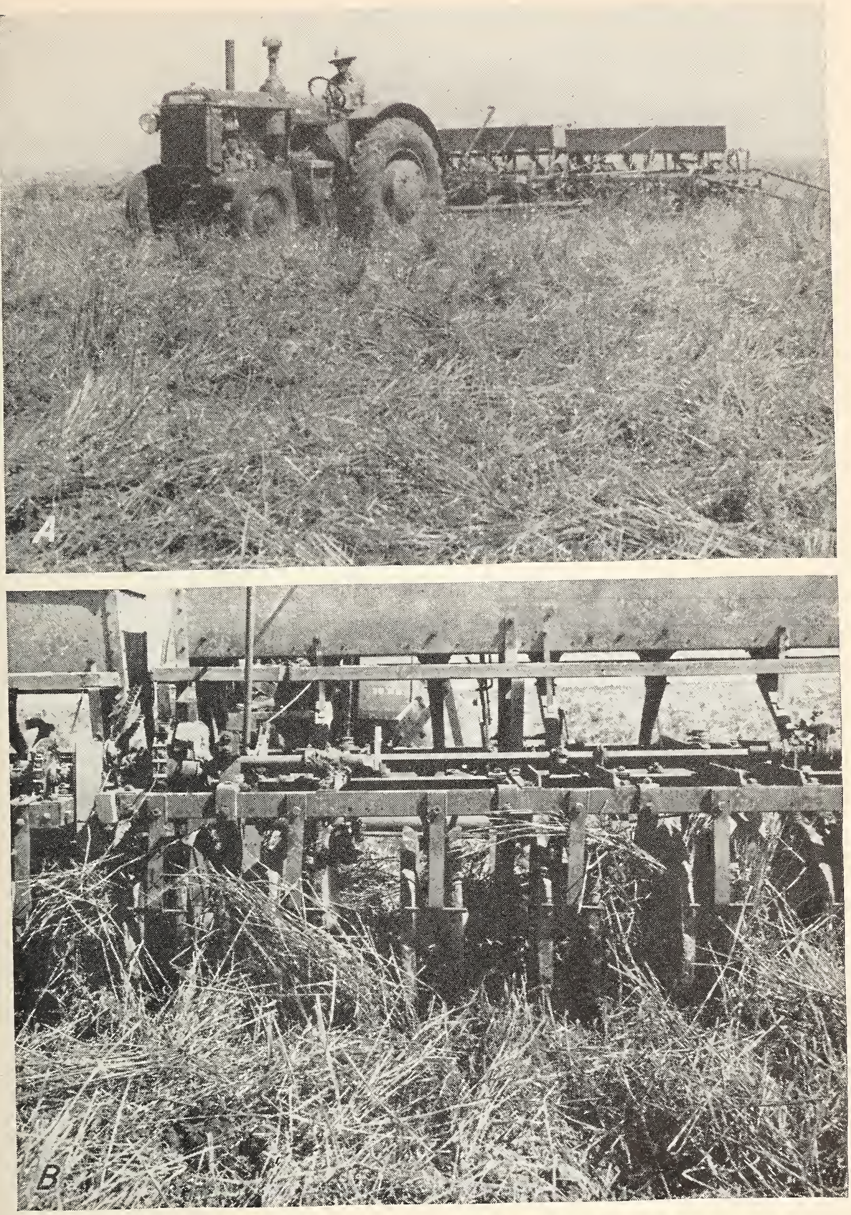

FIGURE 4.—Deep-furrow drill used at the Amarillo experiment station in 1949 for seeding wheat in heavy straw residue amounting to 6,000 pounds per acre. The land had been subtilled previously three times. *A*, general view; *B*, near view of back of machine.

be spaced at least 12 inches and preferably 14 inches apart. When heavy residues have been partly covered with soil by the one-way plow, a disk drill usually works better than a shovel drill. In seasons with average or less than average amounts of residue, either type of

drill will be satisfactory. Moisture will be nearer the surface of the subtilled land in years of low rainfall, and better germination will be secured on such land than on one-wayed land. The usual planting rate, probably 30 pounds of seed per acre, is used.

SUMMARY AND CONCLUSIONS

1. In most years subtilled land in the southern High Plains will produce higher yields of wheat than one-wayed land, exceptions occurring in years with above-normal precipitation when fertility rather than moisture is the limiting factor in crop production.
2. Increased grain yields under stubble-mulch farming appear to be due to depressed nitrification which prevents overstimulation of plant growth, and, in combination with improved soil infiltration rate, makes for an improved moisture-fertility balance.
3. Subtillage tends to conserve organic matter better than conventional farming methods with the one-way plow but has no apparent effect on the phosphorus status of the soil.
4. Observations at the Amarillo station have not shown that subtillage increases damage from insects or winter annual weeds.
5. The practice of raising continuous wheat maintains soil organic matter and porosity at higher levels than does summer fallowing. In periods of deficient rainfall, however, farming on a fallow system may be the only way to produce sufficient plant residues to protect the soil. There will be little difference in the income from a given amount of land when farmed on a fallow and on a continuous-wheat system.
6. The type of subtillage machine developed at the Amarillo station operates satisfactorily on hard-land soils. Implement manufacturing companies are developing or modifying equipment to meet the needs for effective subsurface tillage.

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